Rainfall Shelters

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INTRODUCTION

Rainfall shelters (shelters) have been used during the past 50 yr to exclude rainfall and other precipitation from research plots and lysimeters. They bridge the gap between the controlled environment of a greenhouse or growth chamber and uncontrolled field conditions. Meteorological variables such as radiation and wind are altered under the shelter,[1] but with limited rainfall duration, the effect on crop growth is minimal. The main limitation of rainfall shelters is the small crop area that requires careful extrapolation of results to field areas.

Foale et al.[2] identified the following six subsystems or components of rainfall shelters: site, tracks, shelter structure, drive (mechanism), power supply, and controller. Auxiliary components include in-shelter irrigation systems and cranes for weighing lysimeters. Rainfall shelter subsystems and features are illustrated in Fig. 1, and the references provide examples of various types of shelters.

RAINFALL SHELTER SUBSYSTEMS

Site

The site needs to be representative of the soil to be studied, and the surrounding area must be similarly and uniformly cropped for accurate evapotranspiration measurements.[2] The area needs to be well drained with surface runoff from adjacent areas excluded. Since plot areas are small, isolating individual blocks of soil with vertical walls of plastic film or concrete may be desirable.[2] Utilities such as electricity and telephone service are also desirable, and a water supply of adequate quantity and quality must be available for irrigated experiments. Overall shelter design should allow all or most of the research area to be planted, cultivated, and harvested with farm machinery.

Tracks

Most rainfall shelters have two tracks, but some also have a center track to reduce the structure span or to support a center drive mechanism.[3,4] The center track restricts access to the research area and is not recommended, except for unusual conditions. Tracks may be at ground level for low structures or for structures with support walls (Fig. 1).[5] Tracks may also be elevated to eliminate the support walls, and secondary walls may then be suspended from the structure roof (Fig. 1).[3,4] Foundations for the tracks may be continuous footings or individual piers located along the tracks. Tracks are generally single, I or C section beams of rolled-steel, but angles, railway tracks, and welded-up sections have also been used. In addition to the load of the structure, the tracks must resist upward wind forces and lateral forces in one or both directions.

Structure

Structures consist of the framing, covering, truck assemblies, and any walls or doors. Maximum length is about 30 m, and is governed by the length of time to cover the research area during intense storms. Dual shelters that cover the research area from both ends are sometimes used to increase the length of the research area.[3] Foale et al.[2] provide design information for minimizing the shading from the second shelter. Maximum width has normally been about 12 m, but wider spans are possible with heavier structures and tracks.[6] The height of the structure largely determines the wind loading, and Foale et al.[2] provide excellent wind design information for rainfall shelters. Some structures are designed to be easily moved from one location to another where crop rotations or insect and disease populations require frequent changes in the research location. For example, the shelter by Kvien and Branch[7] was mounted on standard automobile tires rather than tracks and rollers to allow easy movement across a field area.

Construction materials range from light aluminum trusses with fiberglass covering to heavy steel beams and columns.[5,8] The structures are usually covered with fiberglass, aluminum, or steel sheeting. Unless the shelters are in locations with extended daytime rainfall, the light transmittance of the covering is not considered. Walls are omitted on some structures for low crops, but are needed for tall crops, and a taller shelter allows personnel to work inside the shelter.[5] With ground level tracks, walls are attached to the load-bearing columns, and with elevated tracks, the walls are suspended from the roof trusses or beams. On many shelters, walls are placed along the rear

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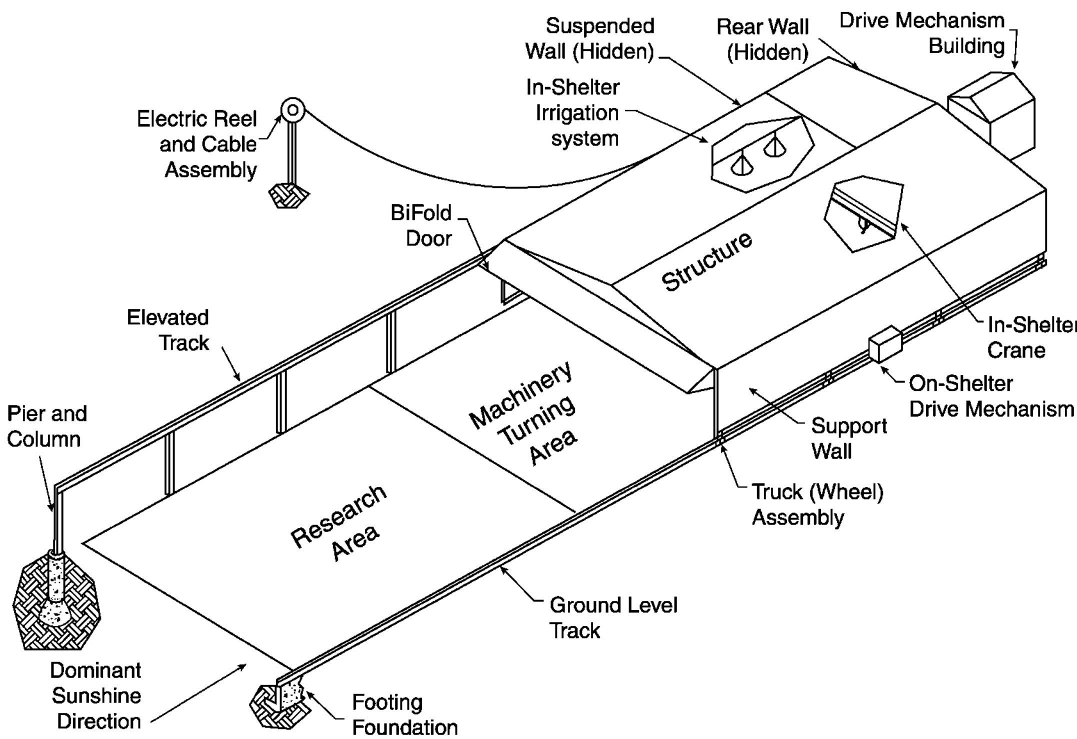

Fig. 1 Illustration of rainfall shelter subsystems and features. All items would not be used on a single shelter.

end of the structure to exclude blowing rain from the research area. On some more recent shelters, bifold doors originally designed for aircraft hangers have been installed on both ends of the structure.[5,8] With both doors open, wind forces in the direction of travel are greatly reduced in comparison to having a permanent rear wall. Truck or roller assemblies are generally placed under the columns of structures with support walls or under the beams or trusses of structures without support walls.

Drive Mechanism

Rainfall shelter drive mechanisms can be classified by the location and type of the drive. Most drive mechanisms have been permanently installed at the rear of the parked structure (Fig. 1).[6] Another approach is to install the drive mechanism entirely on the structure.[5,8] The on-structure location eliminates the separate building to house the drive mechanism and the long drive shaft spanning the distance between the two tracks.

Rain shelter drive mechanisms are of four basic types: cable and drum,[6,9] sprocket and chain,[10] rack and pinion,[3,11] and rack drive.[5,8] The cable and drum mechanism is simply a closed-loop cable passing over a drive drum at the rear end of the shelter and an idler pulley at the opposite end of the tracks. A sprocket and chain drive can use either a closed-loop chain similar to the cable and drum or a drive sprocket traveling along a fixed chain. The rack and pinion is an excellent, but expensive, drive because the machined rack must run along the full length of travel. A rack drive is similar to a rack and pinion, but it utilizes a specially designed drive sprocket that allows a tensioned roller chain to be used in place of the rack. Flexidyne drives now allow the use of independent drives on each side of the structure thus eliminating the long drive shaft across the structure.[5,8]

Power Supply

Alternating current (a.c.) electricity from a reliable utility grid is the preferred power supply because it allows the use of larger motors and heavier structures.[5,6] For starting and reversing the larger motors, three-phase a.c. is preferred to single-phase a.c.[6] If a.c. power is unreliable, especially during storms, it can be used to charge batteries that then power a direct current (d.c.) system.[2] At remote sites without a.c. power, solar battery chargers can be used, or charged batteries can be transported to the shelter.

Control System

A rain shelter control system consists of a rain sensor for initiating movement of the shelter, controls for starting and stopping motors, and mechanisms for safe operation of the shelter and auxiliary components. Initially, rain sensors were collectors with float-activated microswitches or water-activated electrodes.[9,11] Rainfall of sufficient intensity would initiate a control sequence and cause the shelter to move over the research area. After sufficient drainage from the collector through a capillary drain, the shelter would be returned to the parked position. Resistance circuit boards provide the same function with rainfall decreasing the resistance between electrodes and absence of rainfall causing the resistance to return to the normal larger value.[11] The electric pulses from tipping bucket rain gages have also been used to initiate the control sequence.[3,6] After a sufficient time without pulses from the rain gage, the shelter is returned to the parked position. Rain sensors designed for lawn sprinkler systems have been used on rainfall shelters, but they do not accurately sense the end of rainfall.[5]

Rain shelters have been traditionally controlled with timers, relays, and microswitches that followed some logic sequence to start and stop the drive motors.[3,9] The controllers were usually designed by individual researchers to meet the unique features of the shelter. More recently, programmable controllers with input from a rain sensor, microswitches, and transducers have been used to control the shelter motors.[5,6] The control program with complex logic can be developed on a computer, and then downloaded to the controller. Programmable controllers are especially well suited to controlling several motors and meeting numerous failsafe conditions normally required of a complex shelter. Typical failsafe conditions include locking out the drive motors when the doors are closed or when an in-shelter crane scale is attached to a lysimeter.

Auxiliary Components

The most common auxiliary components are in-shelter spray irrigation systems[12] and cranes for weighing lysimeters.[5] Spray systems suspended from the structure frame can be designed for uniform, multiple treatment, or line source irrigation. A bridge crane inside the shelter structure can be substituted for a gantry crane and used to lift, move, and weigh lysimeters. Weighing the lysimeters inside the structure eliminates wind effects on measurements and increases accuracy.[5]

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